Development of luminescent nanoparticles for the detection of pathogen-related diseases in plants

LightMyPath

Ana Brinca-Moreira[1,2,3,4], António José Fernandes[1], Alexandre Faia Carvalho[1], Teresa Monteiro[1], Vincenzo Mondello[4], Cátia Pinto[2], Rita Branquinho[3], Florence Fontaine[4], Florinda Mendes Costa[1]

[1] i3N, Departamento de Física, Universidade de Aveiro, 3810-193 Aveiro, Portugal
[2] Associação SFCOLAB—Laboratório Colaborativo para a Inovação Digital na Agricultura, 2560-312 Torres Vedras, Portugal
[3] i3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, NOVA University of Lisbon and CEMOP/UNINOVA, 2829-516 Caparica, Portugal
[4] USC INRAE 1488 RIBP, Université de Reims Champagne-Ardenne, Campus Moulin de la Housse Bâtiment 18, 51100 Reims, France

Motivation

WHY?

- ✓ **Up to 40%** of the worldwide agricultural **production losses** is due to **plant infection [1]**
- ✓ **EU** commission's directives for **reducing pesticide** use by **30-50%**, until **203**
- ✓ **Grapevine Trunk Diseases (GTDs)** constitute one of the **main cause of vine decline**, **threating the viability of viticulture**
- ✓ **One of the major challenges is the undetermined latency period**, in which the plants **do not display visible external symptom**

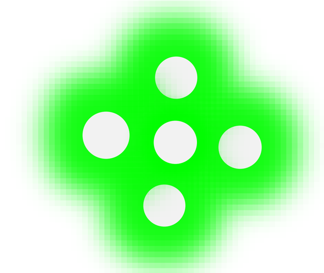
Control & Monitoring

- Scouting: Very time-consuming; Qualified personnel; Prepared installations; Prone to error
- Molecular & Serological: Qualified personnel; Prepared installations
- Remote Sensing: Expensive; External symptoms expression; Indistinguishable signal of abiotic stress

Biosensing Tecnologies → Nanomaterials & Nanostructures

HOW?

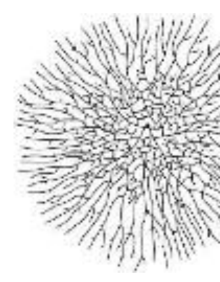
Biosensing Nanoprobes: Transducer — Biological recognition



Persistent Luminescent Nanoparticles (PLNPs)

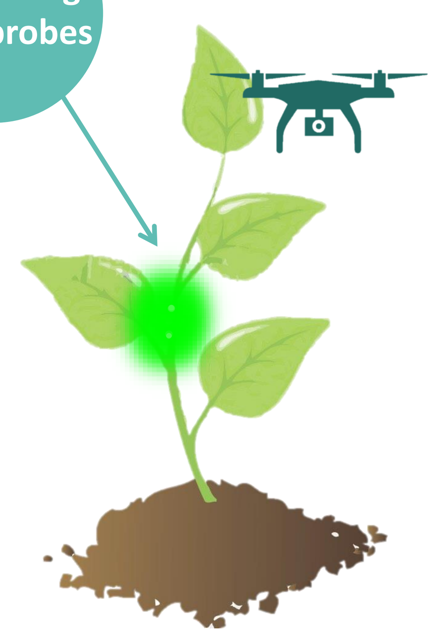
Antibodies

Analyte



Botryosphaeriaceae family

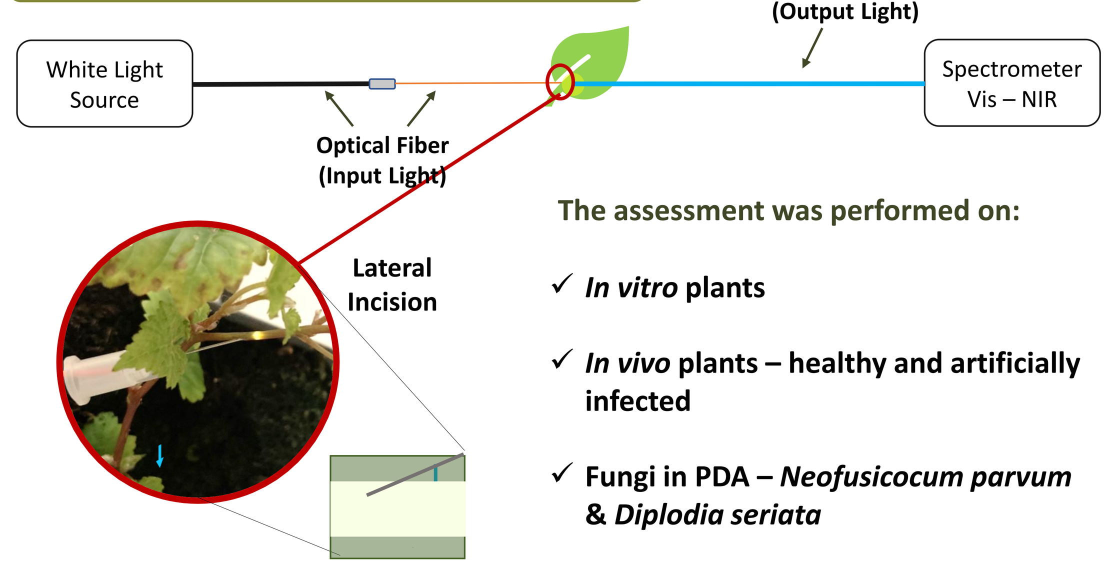
In vivo Bioimaging — Biosensing Nanoprobes



Roadmap & Methodology

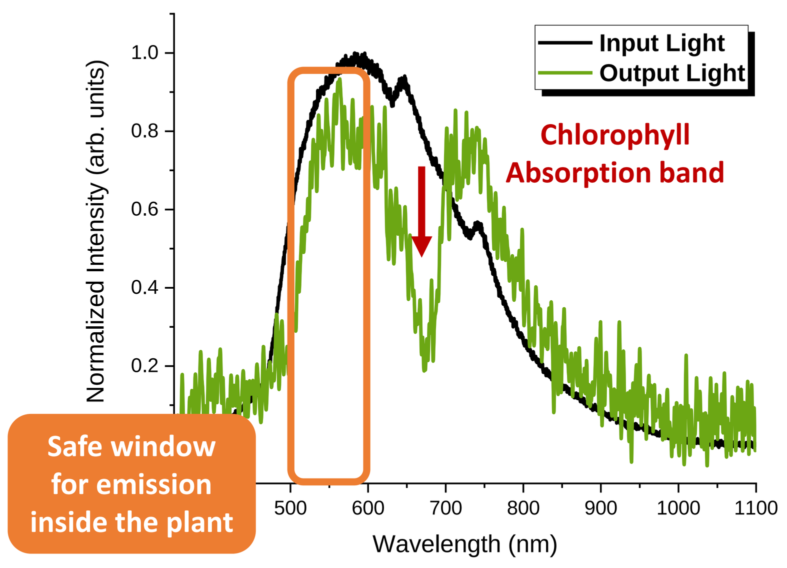
1 Assessment of Grapevine's stem tissues Light Transparency Window

Optical Fiber Experimental Setup



The assessment was performed on:

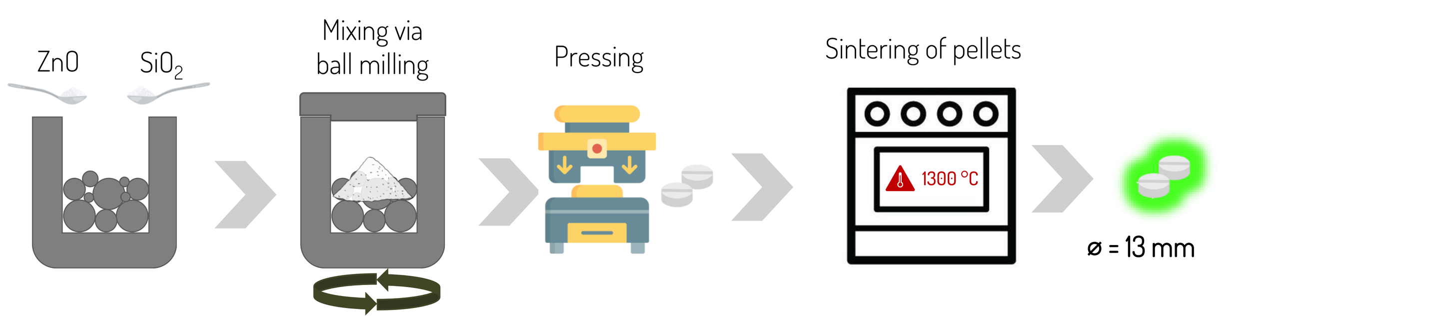
- ✓ *In vitro* plants
- ✓ *In vivo* plants – healthy and artificially infected
- ✓ Fungi in PDA – *Neofusicocum parvum* & *Diplodia seriata*

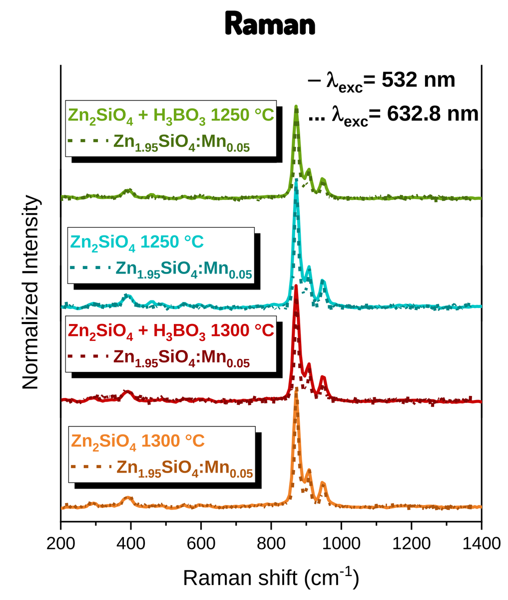


2 Preparation and characterization of Persistent Luminescent Materials

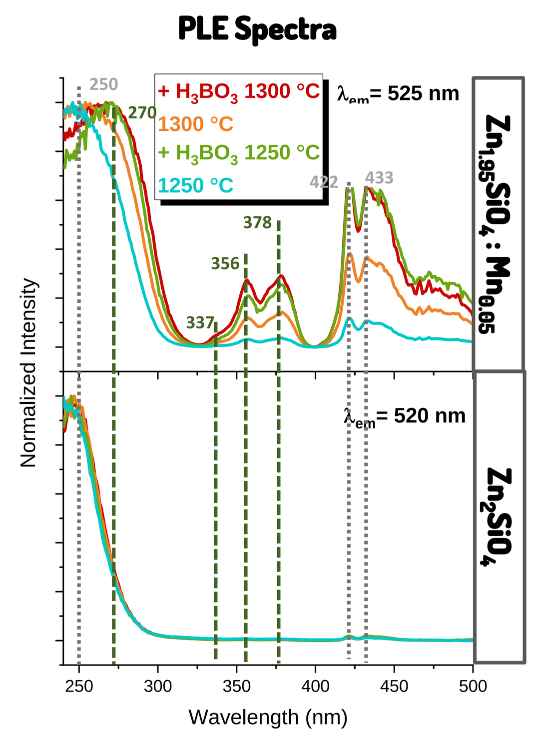
500 nm < $\lambda_{emission}$ < 600 nm ➡ Zn_2SiO_4 doped with Mn^{2+}

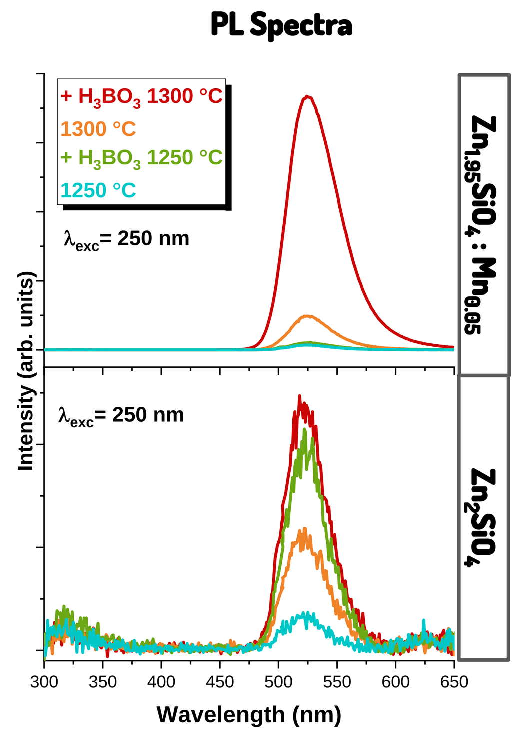
- ✓ Assessment of **Sintering temperature and time**
- ✓ Influence of **H_3BO_3 (5%)**
- ✓ Influence of **doping with Mn^{2+} (2.5%)**

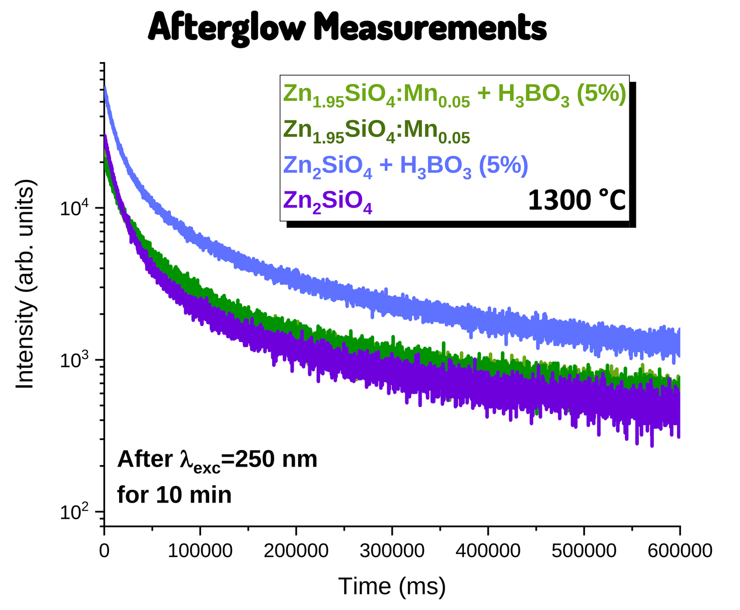




✓ The willemite structure of Zn_2SiO_4 was not influenced by sintering conditions or by the presence of the dopant





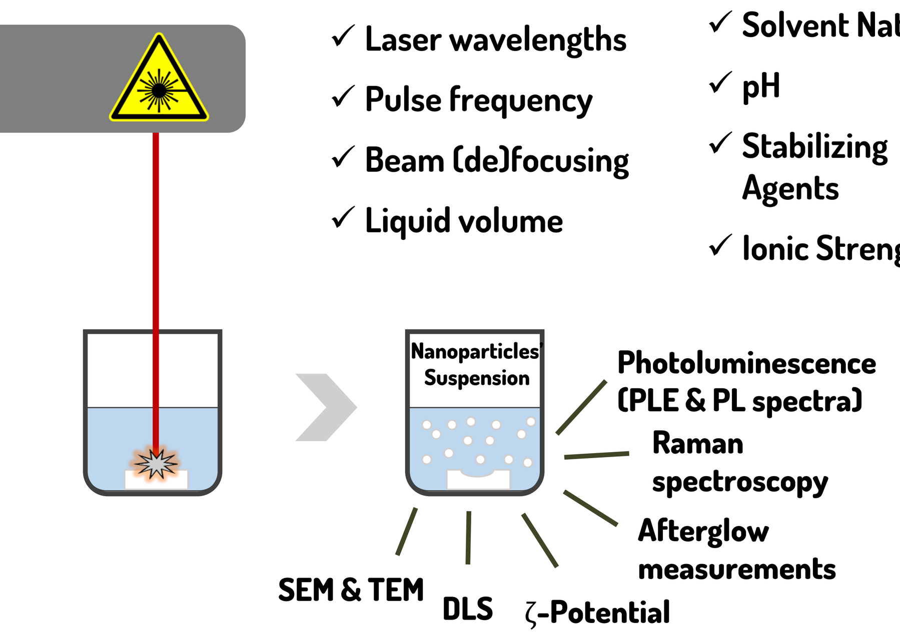


- ✓ The samples submitted to 1300 °C for 2h exhibited higher PL intensity
- ✓ The addition of H_3BO_3 increases the relative intensity of the emission band at 525 nm.
- ✓ 2.5% Mn^{2+} increased the PL intensity, but it displayed a shorter afterglow

3 Preparation of Nanoparticles Pulsed-Laser Ablation in Liquid (PLAL)

Main parameters and conditions to test:

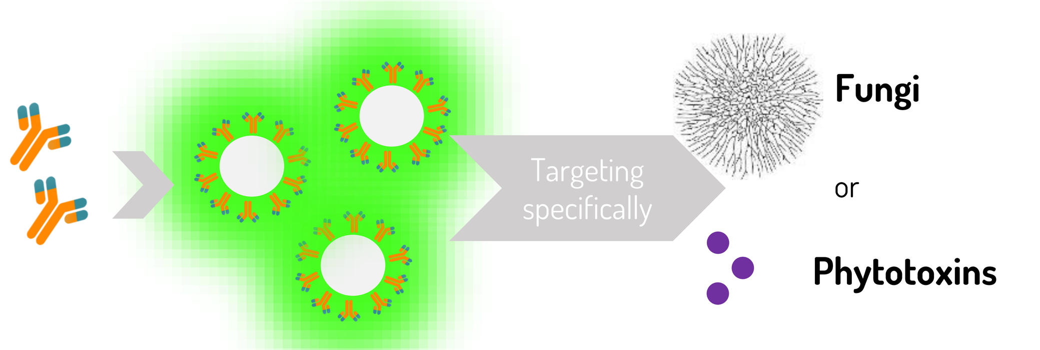
- ✓ Laser wavelengths
- ✓ Pulse frequency
- ✓ Beam (de)focusing
- ✓ Liquid volume
- ✓ Solvent Nature
- ✓ pH
- ✓ Stabilizing Agents
- ✓ Ionic Strengths



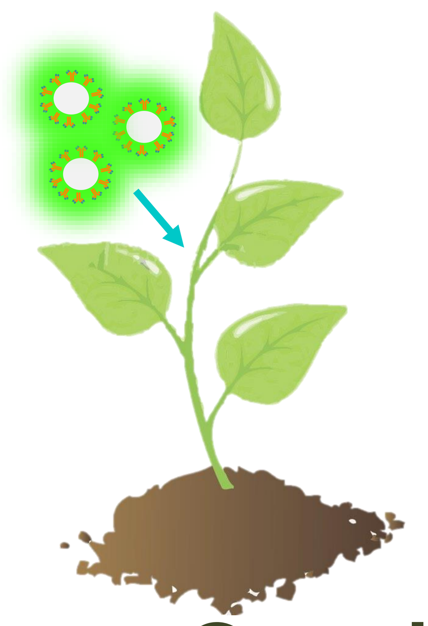
4 Functionalization of Nanoparticles (NPs)

Main goals to accomplish:

- ✓ Acquire antibodies specific to the targets
- ✓ Develop protocol for immobilization of the antibodies onto the surface of the NPs



5 Application and evaluation of PLNPs in plants: *in vitro* and *in vivo*



For evaluation of in-planta interactions:

- ✓ Mechanism of NPs' uptake (stem injection, leaf spraying)
- ✓ Transport of the NPs throughout the plant
- ✓ Toxicity of NPs towards the plant
- ✓ Specificity and sensibility of the NPs response

Conclusions & Future Work

- ✓ The safe window for emission inside Grapevine's stem tissues is between 500 and 600 nm.
- ✓ The addition of H_3BO_3 increases the relative intensity of the emission band at 525 nm and it might play a role in afterglow of Zn_2SiO_4 doped with Mn^{2+}.
- ✓ Concentrations < 2.5% Mn^{2+} will be tested in order to optimize the afterglow.
- ✓ Also, to enhance afterglow, co-doping with Ln^{3+} ions will be assessed in this matrix.

Acknowledgements

This work was developed within the scope of the project i3N, UIBD/50025/2020 & UIDP/50025/2020 & LA/P/0037/2020, financed by national funds through the Portuguese Foundation for Science and Technology, FCT/MECAlso, the authors acknowledge Chaire Maldive financially supported by Grand Reims. Ana Brinca-Moreira acknowledges the PhD grant i3N – FCT UI/BD/152237/2021 and the funding from "Progama PESSOA COTUTELAS 2022" FCT/CampusFrance.
The authors acknoledge Vecteezy.com for offering the use of their pictures.

[1] FAO, "Climate change fans spread of pests and threatens plants and crops, new FAO study," 2021. https://www.fao.org/news/story/en/item/1402920/icode/ (accessed Feb. 23, 2022)